Single Cell Measurements of Important Phytoplankton Processes in EEGLE

Gary Fahnenstiel[1], Steven Lohrenz[2], Kimberly Kelly[2], Richard Stone[1], David Millie[3], Oscar Schofield[4], and Michael McCormick[1]
[1]NOAA, GLERL, Lake Michigan Field Station, 1431 Beach St., Muskegon, MI
[2]IMS, Univ. South. Mississippi, Stennis Space Center, MS
[3]SRRC/USDA, Mote Marine Lab, Sarasota, FL
[4]IMCS Rutgers, Univ., New Brunswick, NJ

INTRODUCTION

During the spring isothermal period in Lake Michigan a bloom of net diatoms occurs throughout the southern basin (Brooks and Torke 1977; Fahnenstiel and Scavia 1987; Fig. 1). This spring diatom bloom (SDB) is a major source of carbon to higher trophic levels and directly influences the health of key benthic invertebrates. At the same time the bloom initiates (March/April), the Recurrent Coastal Plume (RCP) develops in the nearshore region of the southern basin (Fig. 2). The linkage between the RCP and the SDB was a major focus of our project. Because the phytoplankton communities in the SDB and RCP have broad similarities in community composition (dominance by centric diatoms and crypto-phytes), community and broad taxonomic measures lack necessary discrimination. However, at the species level there are distinct differences in the centric diatom communities of the SDB and RCP. The SDB is dominated by large chain-forming centrics, whereas the RCP is dominated by small solitary centrics (5-10 mm; Fig. 1-2).

In order to understand the effects of the RCP on production, growth, nutrient status, and light harvesting abilities of spring diatoms, individual cell or species measurements are needed. One unique aspect of our EEGLE project is that most phytoplankton processes have been measured at several organizational scales, e.g., community, chemo-taxonomic, and individual cell. In this poster we present information on the single cell measurements that are being made as part of our EEGLE project.

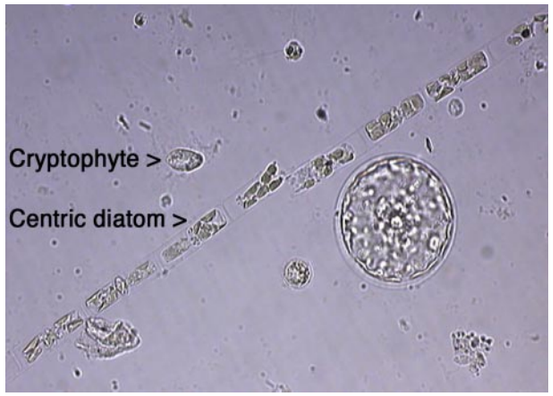

Figure 1. Photomicrograph of particulate material from spring diatom bloom during April 1999. This station was located off Muskegon and was not influenced by the RCP.

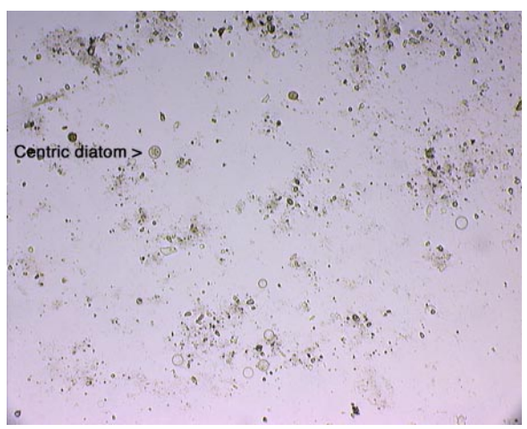

Figure 2. Photomicrograph of particulate material from region impacted by recurrent coastal plume in April 1999. Note abundance of small centric diatoms (arrow) and detrital material.

PHOTOSYNTHESIS AND GROWTH

Photosynthesis and growth rates are being estimated by the incorporation of C-14 into individual cells using track autoradiography (Carney and Fahnenstiel 1987). This technique is basically the standard C-14 method except that the radioactivity is counted as individual disintegrations associated with each cell recorded on photographic emulsion (Fig. 3).

Short-term photosynthesis-irradiance (PI) experiments were conducted to measure the photosynthetic rate of individual species. Longer-term time series of C-14 uptake (24-48 hours) were used to calculate growth rates using the models described in McCormick et al. (1995). A novel aspect of these models is they also can be used to provide an estimate of the species carbon content based only on the change in specific activity.

Preliminary results from the March 1998 sampling demonstrates that in some cases the models do provide different growth rates (Table 1). These differences are due to the length of the photoperiod and assumptions regarding the division cycle. Interestingly, modeled carbon contents are consistently lower than biovolume based carbon contents (30%). Moreover, preliminary data suggests that the RCP is adversely impacting the growth of phytoplankton, as growth rates in the plume are lower than those in non-plume regions.

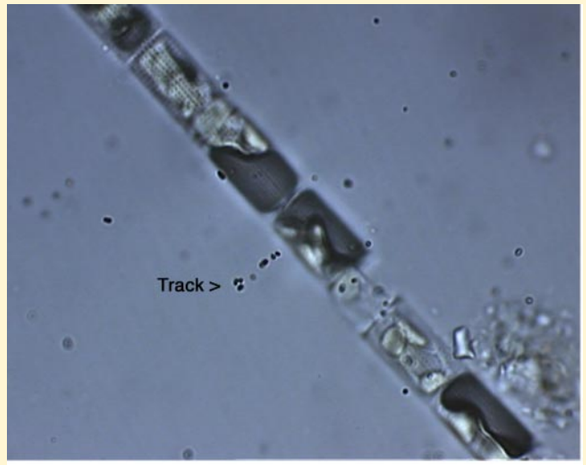

Figure 3. Photomicrograph of *Aulacoseira islandica* showing a disintegration (track) originating from cell.

Table. 1. Growth rates and carbon content of dominant phytoplankton from Muskegon-110 m station on 3/22/98. Growth rates were calculated using the constant uptake division model (CUDM), variable uptake division model (VUDM), and diurnal model (DM) (McCormick et al. 1995). Carbon content of species was determined from output of growth models (DM and CUDM) and biovolume estimates (Strathmann 1967).

	GROWTH RATES (d^{-1})			CARBON CONTENT (µg)	
Species	CUDM	VUDM	DM	Model	Biovolume
Cyclostephanos sp.	0.18	0.30	0.31	5	8
Stephanodiscus sp.	0.25	0.45	0.26	13	18
Aulacoseira subartica	0.19	0.34	0.25	*26*	*38*
Aulacoseira islandica	0.30	0.56	0.23	78	100

LIGHT ABSORPTION

Light is an important variable controlling phytoplankton production and biomass during the spring bloom (Scavia and Fahnenstiel 1987). Because significant light attenuation is associated with the RCP, it may accentuate light limitation and possibility impact the spring bloom. Light absorption efficiency of individual cells was measured as part of this EEGLE project. The poster of Kelly and Lohrenz describes the technique used to measure the optical efficiency of single cells. Information on optical efficiency coupled with spectral irradiance fields and photosynthesis and growth rates can be used to estimate individual cell quantum yields for photosynthesis and growth. With this information we can compare species abilities to utilize light and possible competitive outcomes.

The largest differences in spectral absorption efficiency were associated with algal groups (see poster of Kelly and Lohrenz for more detail on spatial and temporal variability). The spectral shapes varied between cryptophytes and diatoms in Lake Michigan. These differences in light absorption efficiency among species influenced the ability to harvest light (Fahnenstiel et al. 1999).

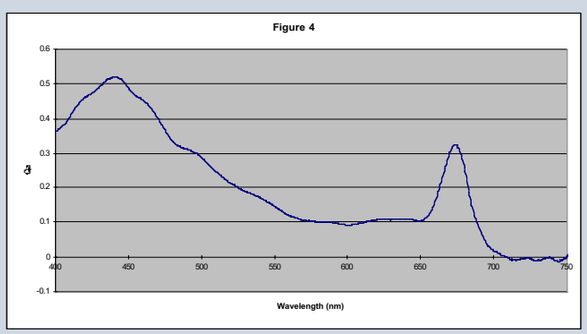

Figure 4. Spectral absorption efficiency of *Cyclostephanos* sp. (small centric diatom abundant in RCP) determined with microphotometrically (see poster by Kelly and Lohrenz). Sample was collected from Lake Michigan on April 16, 1999.

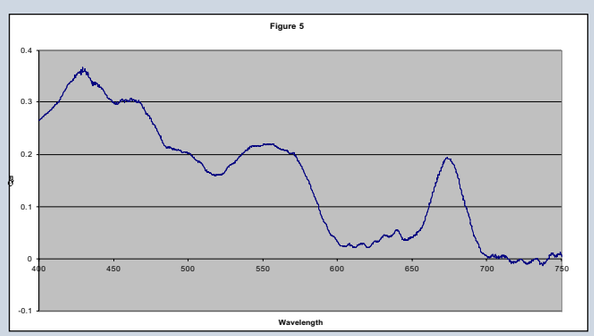

Figure 5. Spectral absorption efficiency of *Rhodomonas minuta* (abundant cryptophyte) determined microphotometrically. Sample was collected from Lake Michigan on April 16, 1999.

PHOSPHORUS AVAILABILITY

Phosphorus is the element most likely limiting phytoplankton photosynthesis and biomass in Lake Michigan (Schelske et al. 1974). To assess the potential for phosphorus limitation we employed two measures of phosphorus availability. Alkaline phosphatase is an enzyme produced in many algal cells when inorganic phosphorus concentrations are low. This enzyme allows cells to utilize organic-P, and is often used as a indicator of possible phosphorus limitation. An enzyme labeled fluorescence technique was used to determine the alkaline phosphatase activity of individual cells (Fig. 6). Also, the presence of poly-phosphate bodies in algal cells was used as a measure of surplus phosphorus. When phosphorus deficient cells encounter surplus phosphorus, this surplus phosphorus is stored in poly-phosphate bodies. A lead-staining technique (Jensen 1968) was used to assess poly-phosphate body formation in individual cells.

Preliminary results indicate that severally P- deficient cells (presence of alk-P) were only found in RCP areas several weeks after a resuspension event. No evidence of strong P limitation was been found in non-plume areas or RCP areas immediately after plume resuspension. Moreover, no evidence for widespread poly-phosphate formation was found in plume or non-plume impacted areas.

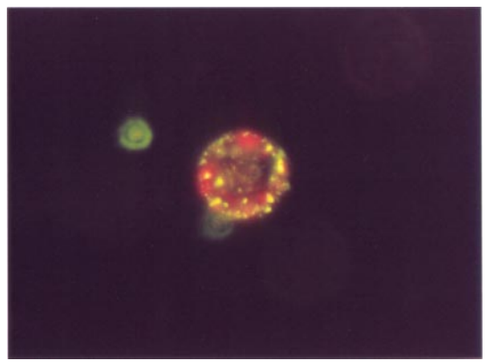

Figure 6. Photomicrograph of small centric diatom (most likely *Cyclostephanos*) exhibiting alkaline phosphatase labeled fluorescence (yellow). The red fluorescence is chlorophyll. The significant yellow fluorescence suggests that the cell was likely phosphorus deficient.

REFERENCES

Brooks, A. S. and B. G. Torke. 1977. Vertical and seasonal distribution of chlorophyll *a* in Lake Michigan. *J. Fish. Res. Bd. Can.* 34:2280-2287.

Carney, H. J. and G. L. Fahnenstiel. 1987. Autoradiography with unialgal cultures: Quantification of track and grain density methods, and evaluation of C-14 loss on preservation. *J. Plankton Res.* 9:41-50.

Fahnenstiel, G. L. and D. Scavia. 1987. Dynamics of Lake Michigan phytoplankton: Recent changes in surface and deep communities. *Can. J. Fish. Aquat. Sci.* 44:509-514.

Fahnenstiel, G. L., S. E. Lohrenz, K. Kelly, D. F. Millie, and O. M. E. Schofield. 1999. Light absorption characteristics of individual phytoplankton cells from a natural community: Examples from Lake Michigan during the winter period. *Verh. Int. Verein. Limnol*. In Press.

Jensen, T. E. 1968. Electron microscopy of polyphosphate bodies in a blue-green alga, *Nostoc pruniforme*.
Archiv fur Mikrobiologie 62:144-152.

McCormick, M. J., G. L. Fahnenstiel, S. E. Lohrenz, and D. G. Redalje. 1995. Calculation of cell-specific growth rates: a clarification. *Limnol. Oceanogr*. 41:182-189.

Scavia, D. and G. L. Fahnenstiel. 1987. Dynamics of Lake Michigan phytoplankton: Mechanisms controlling epilimnetic populations. *J. Great Lakes Res*. 13:103-120.

Schelske, C. L., E. D. Rothman, E. F. Stoermer, and M. A. Santiago. 1974. Responses of phosphorus limited Lake Michigan phytoplankton to factorial enrichments with nitrogen and phosphorus. *Limnol. Oceanogr.* 19:409-419.